LELAND STANFORD JUNIOR UNIVERSITY.

Ralph Arnold: 'The Paleontology and Stratigraphy of the Marine Pliocene and Pleistocene of San Pedro.'

Thomas Andrew Storey: 'Some Studies on Voluntary Muscle Contraction.'

BRYN MAWR COLLEGE.

Margaret Baxter MacDonald: 'A New Class of Disulphones.'

UNIVERSITY OF CALIFORNIA.

Alice Robertson: 'The Embryology and Embryonic Fission in Cyclostomatous Bryozoa.'

CLARK UNIVERSITY.

Andrew J. Kinnaman: 'Mental Life of two *Macacus Rhesus* Monkeys in Captivity.'

COLUMBIA UNIVERSITY.

Nevil Monroe Hopkins: 'Some Experiments on Electrolytic Conductivity with Reference to the Ion Theory.'

SYRACUSE UNIVERSITY.

William Erastus Taylor: 'On the Product of an Alternant by a Symmetric Function.'

UNIVERSITY OF VIRGINIA.

Heber D. Curtis: 'Definitive Determination of the Orbit of Comet, 1898, I.'

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*RECENT PROGRESS IN ASTRONOMY.**

THE opening years of the twentieth century are full of remarkable and most striking evidences of man's power over the forces of nature, and yet with this feeling of might there comes to the thoughtful student, and perhaps especially to the astronomer, a deep reverential feeling of man's utter insignificance, and the littleness of his knowledge, in comparison with what is necessary for the complete mastery of the problems that present themselves.

Heat, light and electricity are the forces which have been so grandly made use of by the scientific man and the practical engineer. It is enough for me to refer only to the stupendous developments of the machinery making use of steam for locomotion on land and sea; to the great labor-saving devices used in the manufacture of steel and other needed things.

Still more marvelous are the applications of electricity; and the promises for the near future are most startling. I do not desire to develop these lines of thought, because I am aware that the young men of this institution, and especially those of the graduating class, have minds well stored with apt illustrations; and their imaginations can rapidly construct dreams of the future, based upon their own intimate knowledge of what has been done, and what is just on the point of being accomplished, by the application of heat and electricity.

This morning in my short address I wish to call your attention to *some* of the triumphs lately achieved by the use of light. And inasmuch as my work is mainly astronomical you will, I know, permit me to dwell entirely on the matter of celestial photography.

The United States has many reasons to be proud of what her astronomers have done both in the improvement of photographic telescopes, and in the results of photographic research; but the whole world has been active in applying this comparatively new instrument. The promise of future developments is indeed very gratifying. Every one is deeply interested in the study of the make-up of the solar and lunar surfaces. To-day photographic telescopes supply us with most of our accurate knowledge of details.

Exposures on the sun are made, lasting one to several thousandths of a second of time, which on development bring out the texture of the photosphere, the details of spots and spot groups, and the faculæ. These plates are taken with great regularity at several observatories in the world, and are studied at leisure by a trained force of observers. Rutherfurd in New York City from 1870 to 1874 took many solar photographs, the study of which has given us

* Commencement Address delivered at the Worcester Polytechnic Institute, June 12, 1902.

much valuable information. And since his time Greenwich, Paris, Meudon, Mt. Hamilton (Lick), Harvard, Yerkes and other observatories have taken thousands of plates. Many of my audience have seen such pictures thrown on a screen by the aid of a lantern, and thus have been able to study sun-spots, photosphere and faculæ in a most instructive and accurate way.

The earth's only visible satellite has always stirred the interest of the astronomer. Schmidt, of Athens, Beer and Mädler, of Germany, and many others have spent years of labor in making topographical drawings of the moon, and they published very fine maps. Thirty years ago Draper and Rutherfurd showed the world what excellent photographs could be taken with wet plates, and from that time many of the great observatories have collected hundreds of photographs of the moon on the very sensitive dry plates of recent years. We have now exquisite plates to study and measure. Lately the French government has published exact heliogravure copies and enlargements of the lunar photographs taken by Loewy and Puiseaux.

In this connection it is proper to call attention to the difference between an object glass for seeing and one for photography. The yellow rays affect the eyes most readily and so the lenses must be ground to bring those rays to a focus. But the blue and the violet rays affect most the photographic film. So that with a telescope arranged for seeing, the photographs obtained, in most cases, are hazy and indistinct. Rutherfurd, therefore, placed outside of his seeing object glass a lens of flint glass, so arranged as to bring the blue rays to a focus. It was with such a lens that he obtained his fine plates of the sun, moon and stars.

To-day this same system of lenses is mainly used, or a system involving the same principle. Lately, however, there has been discovered at the Yerkes Observatory a new method which gives great promise. When the University of Chicago bought the forty-inch object glass, they were unable to raise the money to buy the needed extra lens, which would enable them to photograph well the moon and other heavenly bodies. Fortunately, this was so, for it resulted in experiments by Mr. Ritchey which demonstrated the fine results to be obtained by a screen. This screen of colored glass was put in front of the sensitive plate, and allowed only the yellow and red rays to pass through the plate—it kept out the blue and violet rays—and, therefore, only those rays reached the sensitive plate which were accurately focused by the object glass. The result was some splendid photographs of the moon and its details, as fine as anything so far obtained. This discovery of the use of a proper screen gives the promise of converting any good seeing refracting telescope into a fine photographic instrument with very small expense.

The reflecting mirror when properly shaped brings to one focus all the rays of light; as well those rays which affect the eyes best as those which produce the desired result on the sensitive film. This fact has brought into increasing use the reflectors of large and small diameters. Modern methods of producing and mounting silver-on-glass mirrors have brought into considerable prominence the reflector especially for photographic work.

Gathering together all the photographs made from the time of Rutherfurd (1874) to the present, and later, will put into the hands of the selenographer means of determining the changes on the moon. Changes we most certainly expect. We are not aware that there exists anything which does not undergo change. But these changes may be so small and so slow to us that it may take years to discover them.

The surroundings of the sun—that region

which comes into view only at the times of total solar eclipses—the sun's 'crown of glory,' the corona—at present can be studied for about an hour during a century, if we estimate the time the astronomer has been able to actually see the corona.

But photography has here brought us most satisfactory results. Many negatives are now obtained at every eclipse of the sun, and these can be studied and measured at leisure. At an observing station for a total solar eclipse, the astronomer of fifty years ago would be dumbfounded to see how few and how small are the instruments set aside for the eye observations. All the large instruments and most of the observers' time are given to the photographic work. How fortunate this is—for not only can the originals be studied with great care, but copies can be furnished to all astronomers the world over for inspection and for comment.

In the past the discovery of new planets always excited a deep interest in the minds of men. To-day we are so accustomed to the discovery of new minor planets (sometimes as many as twenty-eight in one year) that we pass them by without much notice. You no doubt remember that the astronomers of the eighteenth century had great faith in Bode's law. This law stated that the planets were arranged in order of distance from the sun according to the numbers, 4, 7, 10, 16, 28, 52, etc. These numbers were obtained by writing down the numbers 0, 3, 6, 12, 24, 48. All the numbers after the second were obtained by multiplying the preceding number by two; and then adding four to each result. Representing the earth's distance as 10 the other numbers represented very fairly the distances of the other planets, but there was a break at 28. No planets were known at the distance 2.8 times the earth's distance from the sun. The law was so firmly believed in that in the latter part of the eighteenth century a number of astronomers joined in the search. They were dubbed the 'celestial police.' The first fugitive planet was found by Piazzi, January 1, 1801, an astronomer of Sicily, who had not yet received notice of his appointment on the force.

Then the search was later taken up most vigorously, and down to 1892 about 325 were discovered. But in the latter part of the preceding year Dr. Wolf, of Heidelberg, inaugurated the scheme of photographing the heavens. He made his exposures in duplicate, and for two or three hours. The result was that if a minor planet was in the field, as the telescope was guided by following accurately a star, the planet's moving caused a short dash to appear on the plate instead of a round star image.

The plates were measured and from these measurements the astronomer could determine whether the planet was new or an old one. In carrying out this work Dr. Wolf, Charlois of Nice, and others have been so successful that, since November 28, 1891, the list of minor planets, mainly discovered by photography, has increased to nearly five hundred. Wolf's work attracted the attention of the late Miss Catherine Wolfe Bruce, of New York City, who has done so much for astronomy. Miss Bruce gave Wolf the means to build a fine photographic outfit. The new apparatus he had built in this country, and is now using with the most excellent results. He has immortalized that noble, generous woman by naming one of the planets Brucia. He showed his appreciation of the work of the Lick Observatory by giving the appellation of California to the planet he discovered on September 25, 1892, and he had previously named another Chicago, after the city he expected to visit during the Exposition of 1893.

Photography has so rapidly increased the number of these little planets that there has been some serious discussion as to whether

it may not be wise to let them go; the calculations and observations necessary to keep track of them are considerable and expensive.

This method by the use of larger lenses, longer exposures and more sensitive plates, may show thousands of little bodies, circulating not only between the orbits of Mars and Jupiter, but even between the orbits of all the other planets.

If celestial photography had been known in 1846 and previously, then the discovery of Neptune would have been made by Challis at Cambridge, England, with great ease.

It was by photography that Herr Witt in 1898 discovered that most interesting minor planet named by him Eros. This is the first body whose orbit has been proved to lie mainly within the orbit of Mars—moving in such a path that at perihelion the earth and planet are separated by about 15,000,000 miles. Here, then, we have a grand opportunity for determining its parallax and so getting a new value of the sun's parallax, and hence its distance in miles. Such use has already been made of Eros. A large number of observatories took in 1901 photographs of the planet, and these are to be measured and reduced. But Eros will be better situated in later years, so that during the twentieth century the sun's distance will be obtained with great accuracy. To-day we know that distance with an uncertainty of about 150,000 miles —at the end of the century the uncertainty ought to be reduced to 25,000 miles or less. Under the most accurate methods of the present day base lines on this little earth can be measured with an error of even less than one part in a million—or one inch in a million inches, *i. e.*, one inch error in measuring a line nearly sixteen miles long, or half an inch error in measuring a line nearly eight miles long.

Such accuracy we can hardly hope to reach during the twentieth century in obtaining the distance of the sun from the earth. Such an error would amount to over ninety miles. One mile seems a large unit to us, but it is an exceedingly small measuring unit for sounding the depths of space.

The business men of the world are proving to us that there is a great benefit for some one in big combinations of shops and men. The effect in some cases has been to improve machinery, better the output and to reduce prices. This idea of cooperation has taken hold of the scientific mind. To-day seventeen observatories are engaged in making maps of the heavens by photography. Seventeen observatories from Finland to the Cape of Good Hope have been busy for the past ten years in obtaining the images of stars on the sensitive plates. Their plan is a most interesting one for the astronomer. It was arranged by conferences of astronomers who met several times at Paris. The heavens have been divided into belts parallel to the equator, and each observatory photographs one or more belts completely around the sky. In order to guard against error a peculiar system has been adopted; each plate is exposed for twenty seconds, the telescope in the meantime following the star with great nicety. Then the plate is moved a trifle and another exposure is made lasting three minutes, and in a similar way a third exposure is made for six minutes. These three images of a star are very close to each other. Every *bright* star will make three images. The *faint* stars will give only two images and the *very faint* stars one image. This enables the astronomer to judge of the brightness of the stars, and also to discriminate between defects on the plate and real images. In order to tie a plate to its neighboring plates they are made to overlap, so that twice the number necessary to once cover the sky is taken. This makes 22,000 plates. Many of these have now been made and the plates have been measured to de-

termine the relation of the stars to each other. The catalogue to be published is likely to contain about 2,000,000 stars down to the 11th magnitude. When done, we shall have the most valuable and extensive star catalogue ever constructed.

In addition to these plates the observatories doing this work will also take plates with exposures lasting thirty to fifty minutes (depending on the atmospheric conditions). These plates will probably show some 20,000,000 stars.

To measure their positions and to reduce the measurements would require much time and money—more than the astronomers and their patrons can afford to give. It has been decided, however, to enlarge these plates by proper lenses and to make a heliogravure of the enlargement. The liberal French government has been the first to publish a large number of these charts, which show stars down to the fourteenth magnitude and are invaluable for studying at leisure a given part of the sky. Each plate covers about four square degrees.

In our own country Professor E. C. Pickering, of Harvard College Observatory, has employed the Bruce telescope and other instruments to make photographs of the heavens. Pickering by his system is able to take a larger area on each plate and finish his survey in a shorter time. He has thus been able to collect a magnificent library of plates which have proved most valuable in the past and are likely to prove more precious in the future. Professor Barnard and others have given considerable time to using instruments which show large areas of the heavens with exposures of several hours. The wonder-exciting result is obtained showing that the number of stars goes on increasing. When will it end? What does it mean? The astronomer bows his head in awe-full ignorance!

To-day we are all amazed by the promises of wireless telegraphy. Messages across the ocean seem likely to be coming soon from every direction without going through cables.

Wireless telegraphic communication with the sun, planets and stars the astronomer has had for some time past. The messages are received by a specially devised apparatus called a photospectroscope, and the cipher dispatches are styled spectra. These spectra are photographed on glass and are measured, reduced and interpreted by the expert. In the use of this instrument our own country has done much, and the names of Young, Pickering, Langley, Keeler, Campbell, Hale and others stand high in the list of astrophysicists.

What are the stars made of? What materials are in the sun and in comets? in nebulæ? The light from these bodies speeds onward with a velocity of over 180,000 miles a second and takes more than four years to come from the nearest star. Even to come from the sun requires about 500 seconds of time. These light vibrations enter the telescope and pass into the spectroscope, and proper apparatus enables us to obtain a message which tells us what are the gases in the sun, stars, comets and nebulæ.

Moreover, this resultful instrument gives us the power to determine motion and its rate to and from the observer. The stars are so distant that a line 93 millions of miles in length would look to the inhabitant of the *nearest star* as a line about two-tenths of an inch long would appear to you when placed a mile away!

Motion to or from us of an object so far away has hitherto been impossible to measure. The spectroscope solves the problem. If a star is moving toward us then there is a displacement of lines in the stellar spectrum toward the blue end, and if it is going from us the displacement is to the red end. By proper comparison-measurements the rate of motion can be worked out. This

information is most important for the purpose of calculating the orbit or path in space of the star examined.

Then, too, the same principle gives us the power to measure the rotation times of the sun and planets, because we can bring into view two opposite sides of the sun or the planet's disk; these opposite sides revolve, one toward us, the other away, and the spectra of the two sides show displacements of lines in opposite directions. The amount of displacement gives the velocity of rotation. For the sun and planets these results obtained by the spectroscope are checked by independent observations, such as watching the spots on the sun and on Jupiter.

The power of the spectroscope to measure motion in the line of sight has recently been used by the late director of Lick Observatory, California, Keeler, and by the present director, Dr. Campbell, in solving two most interesting problems. When Saturn's rings were first discussed it was thought they were solid. Then it was shown that a ring system nearly 170,000 miles in diameter and about 100 miles in thickness could not endure, without destruction, the diverse pullings due to the gravitation of forces exercised by the planet and the satellites. A fluid system of rings was found to be unstable also, and the theory was adopted that the rings are composed of millions of small satellites so aggregated that they reflected sunlight to us and gave the appearance of solidity, like a cloud in the summer sky. This theory of the structure of the rings was styled the meteoric theory: it rested almost entirely on the mathematical argument. But Keeler in 1895 confirmed this theory in a beautiful manner by the use of his spectroscope. The slit of the spectroscope was made to pass through the center of the image of the planet and through the rings, and he obtained a photograph of the spectra of the rings and the planet. Then, on examination, the lines in the spectra were found to be conspicuously inclined, and inclined in such a way that the planet was shown to be revolving as a solid body, while the rings were revolving only as they could revolve if composed of separated satellites. Thus we have the final proof that the rings are neither solid nor liquid, but are meteoric. Keeler's results have been confirmed fully by other observers.

The question has often been asked, 'Does the solar system as a unit remain fixed in space, or is it moving in a known direction?' How can this be determined? When we look down a long straight line of railroad track we note that the separate tracks appear to come closer together as the distance sighted becomes greater, and if the distance is long enough the tracks appear to actually come together. Now if we walk down the track we discover that this coming-together point moves away from us—the tracks open in the direction we are walking and on looking back the tracks appear to be closing in. An effect similar to this would show itself when we look at the stars, if the solar system is moving in space. Those stars, situated at the point towards which we are moving, will gradually open out, separate, and those stars in the opposite direction would appear to be coming together.

Observations have been made to determine these directions; with the result that they seem to show that the sun, carrying with him his family of planets, is moving towards a point near the eastern edge of the constellation of Hercules, with a velocity of about fifteen miles a second. But observers differ quite a little in their results. Campbell has undertaken to investigate the subject by studying the velocity of stars in the line of sight by the use of the spectroscope. The examination of many hundreds of stars ought to bring out the result, that in the direction we are moving the general average displacement of lines in the spectra

should be toward the blue end, and the opposite effect would show itself in examining stars in the direction *from* which we are moving. Campbell has examined many stars in the northern sky, and soon will go to Chile to continue his observations. The final result will give us both the point among the stars toward which the solar system is going and the velocity. These facts being known, the astronomer may be able in the future to calculate when the sun and his family will come into dangerous proximity to other great systems in space. Such thoughts need not worry us as the time is to be reckoned in thousands of years!

The spectroscope applied to sun, planets, stars, nebulæ, comets and meteors, has given us a splendid record, and the present century is full of promises of greater results.

To-day in all great observatories photography is used to obtain permanent records of sun, planets and stars, etc. When we study the photographs taken, we are impressed with the fact that our sensitive plates, when exposed to an object, will show on development more and more, depending on the time of exposure. The startling information is obtained that after from ten to twenty-five hours or more exposure we can obtain a photograph which will show us what we never can hope (as far as we now know) to see in our telescope! Let us give our imaginations free rein, and we may dream of getting only general information with our eyes, but by the use of sensitive plates in photography we may make amazing discoveries all around us of things the eye cannot see.

In conclusion let me quote the words of one of our ablest workers in celestial photography:

"If we were asked to sum up in one word what photography has accomplished, we should say that observational astronomy has been revolutionized.

"There is to-day scarcely an instrument of precision in which the sensitive plate has not been substituted for the human eye; scarcely an inquiry possible to the older method which cannot now be undertaken upon a grander scale. Novel investigations formerly not even possible are now entirely practicable by photography, and the end is not yet.

"Valuable as are the achievements already consummated, photography is richest in its promise for the future. Astronomy has been called the 'perfect science'; it is safe to predict that the next generation will wonder that the knowledge we have to-day should ever have received so proud a title."

Columbia University. J. K. Rees.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. SECTION I, ECONOMIC AND SOCIAL SCIENCE.

In the absence of Hon. Carroll D. Wright, Commissioner of Labor, Mr. John Hyde, Statistician of the Department of Agriculture and Vice-president of the section for the Denver meeting, presided over the Section. On the afternoon of June 30 the vice-presidential address of Mr. Hyde, on 'Some Economic and Statistical Aspects of Preventable Diseases,' was delivered. The address will be published in full in Science. Meetings for the reading of papers were held on the morning and afternoon of July 1, the morning and evening of July 2 and the morning of July 3. The meeting on the afternoon of July 1, at which the papers of Messrs. Alvord, Powers, Beal and Lazenby were read, was held jointly with the Society for the Promotion of Agricultural Science.

Titles and abstracts of the papers read in full are as follows:

Economic Situation of Pittsburgh: George H. Anderson, Secretary of Pittsburgh Chamber of Commerce.

Greater Pittsburgh, comprising Allegheny County, ranks fourth in population